Summary and Statistical Analysis of the First AIAA Sonic Boom Prediction Workshop

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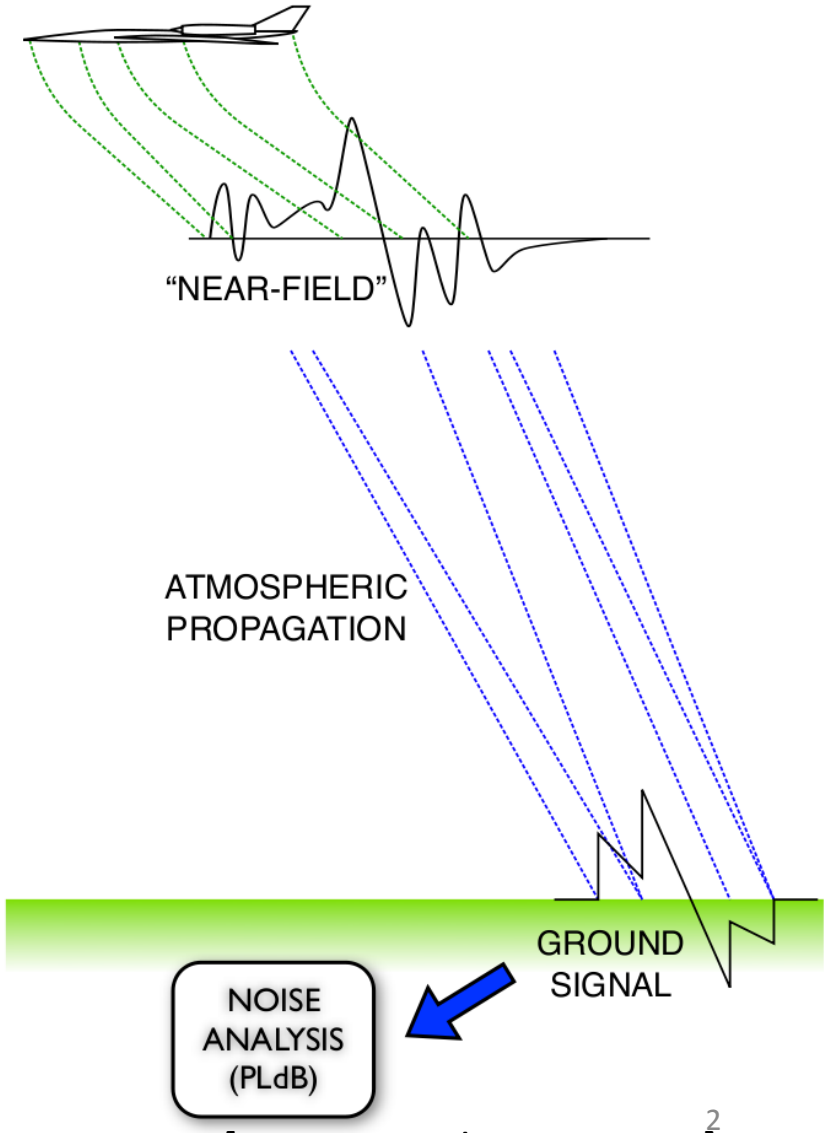
Workshop Objective

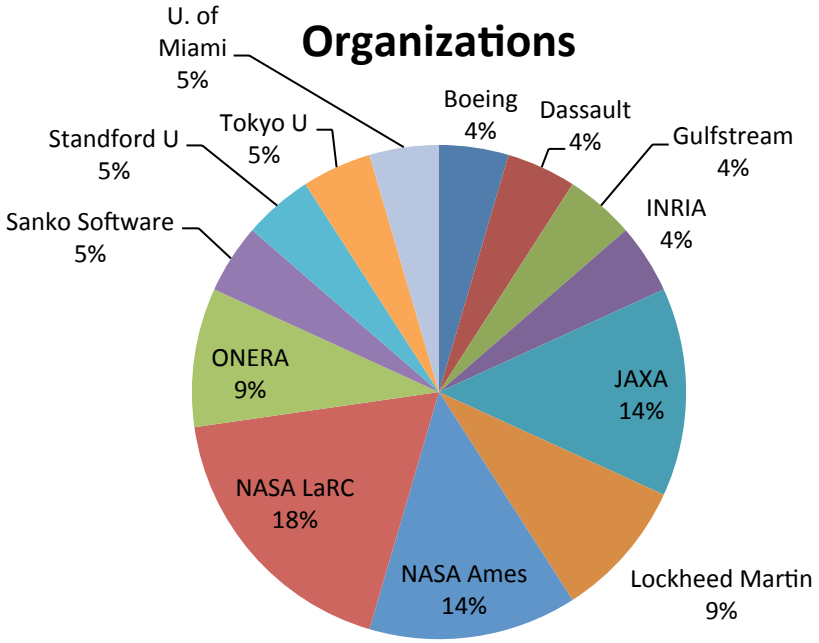
- Assess state-of-the-art near-field CFD as part of sonic boom prediction
- Impartially compare relevant measures of near-field signatures to each other and wind tunnel measurements
- One-day workshop before SciTech 2014
- Following successful AIAA workshop model



[image: Mathias Wintzer]

Participants

- 19 groups
  - Individuals and collaborations of up to 5 people
  - 13 US, 3 France, and 3 Japan
  - 10 Government, 5 Companies, 4 University



Models

[image: Aftosmis, Nemec AIAA-2014-558]

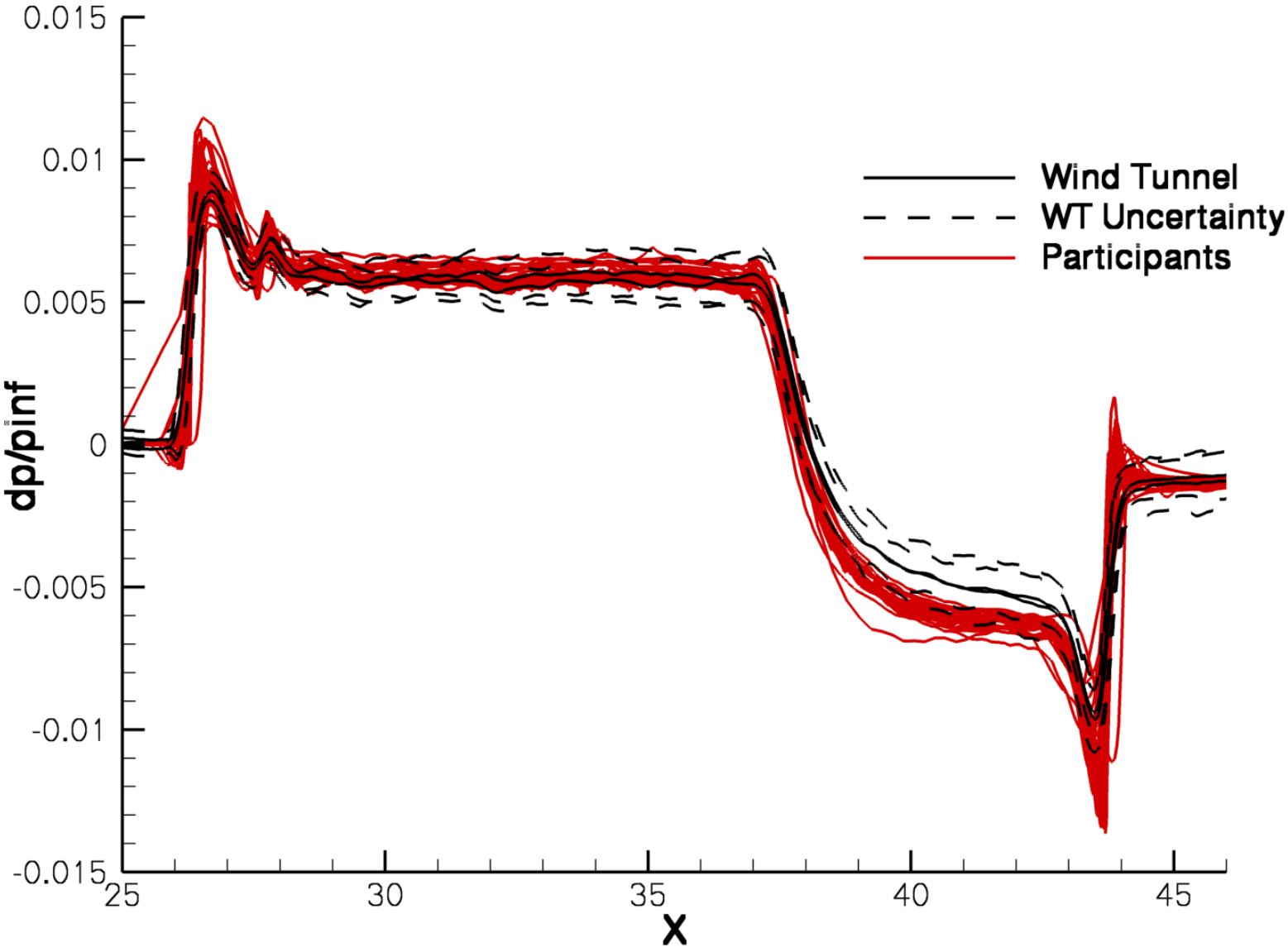
SEEB-ALR

- Axisymmetric body designed by Lockheed Martin for the validation of a flat-top signature design method
  - Seebass and George with aft lift relaxation
- 18in long, examining at H=21.2in, 42.0in
- Mach 1.6

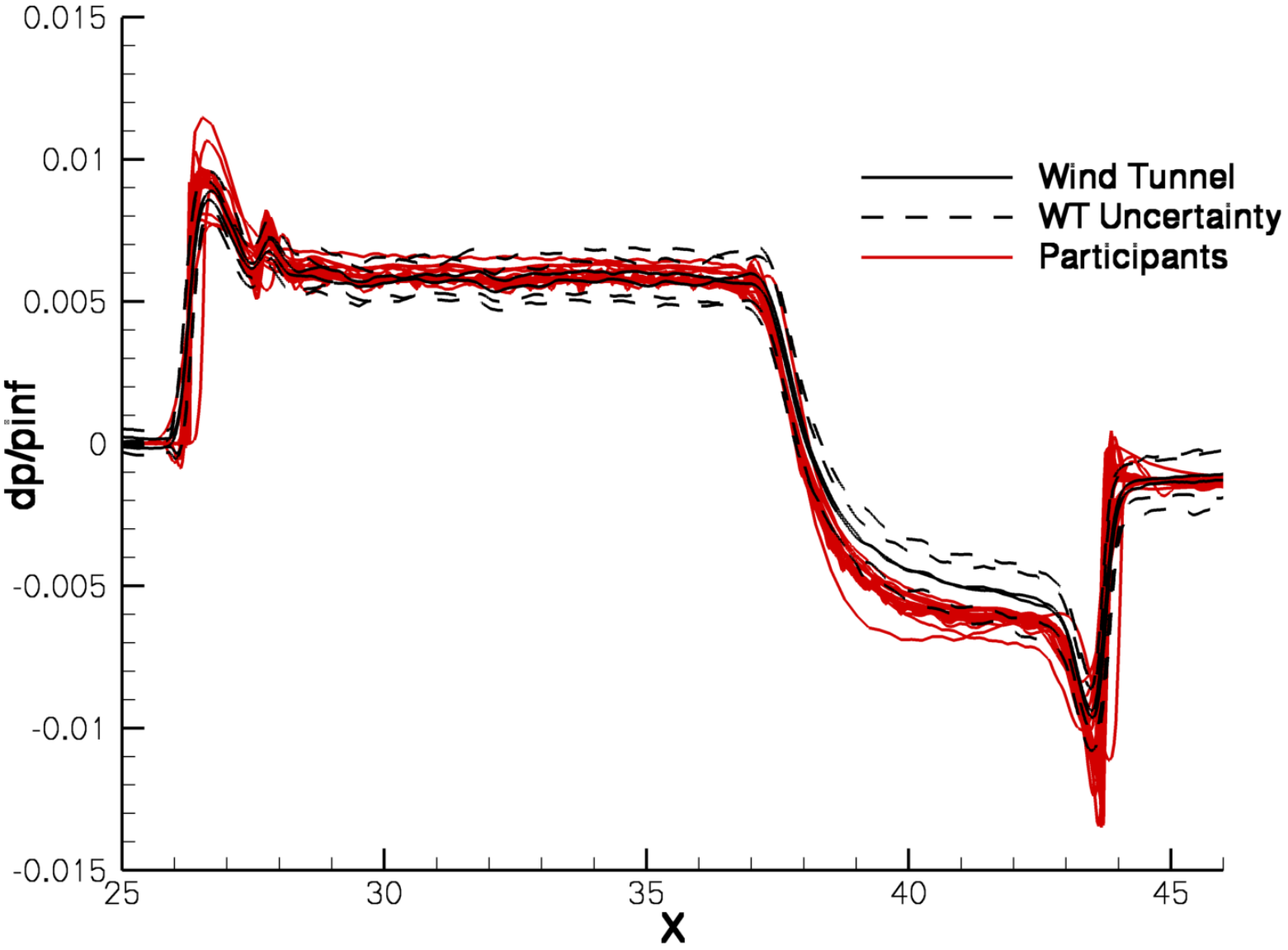
SEEB-ALR Signatures

- 64 extracted signatures (2 locations)
  - 45 workshop provided grids
    - Uniformly refined unstructured mixed-element and purely-tetrahedral
    - Point-matched structured (every other node)
  - 19 participant provided grids
    - Fixed and solution adapted
  - 28 tetrahedral, 16 mixed, 10 structured, 5 overset, 3 Cartesian, 1 hybrid, 1 linear
  - 57 Euler, 4 SA, 1 laminar, 1 SST, 1 linear
  - 12 new or updated since the workshop

All SEEB-ALR H=21.2in

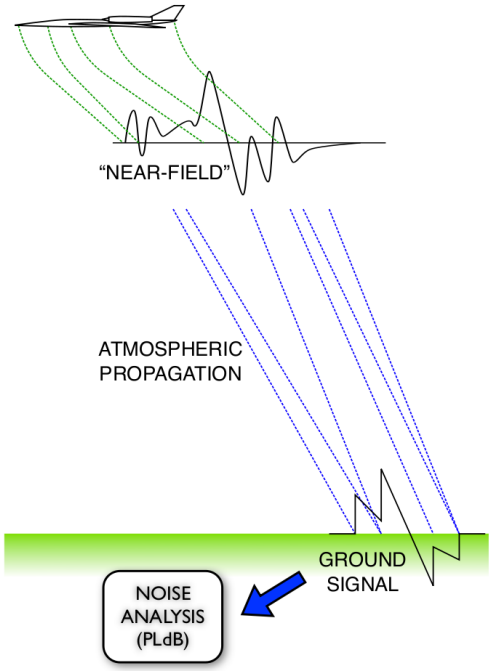


Finest-Grid SEEB-ALR H=21.2in

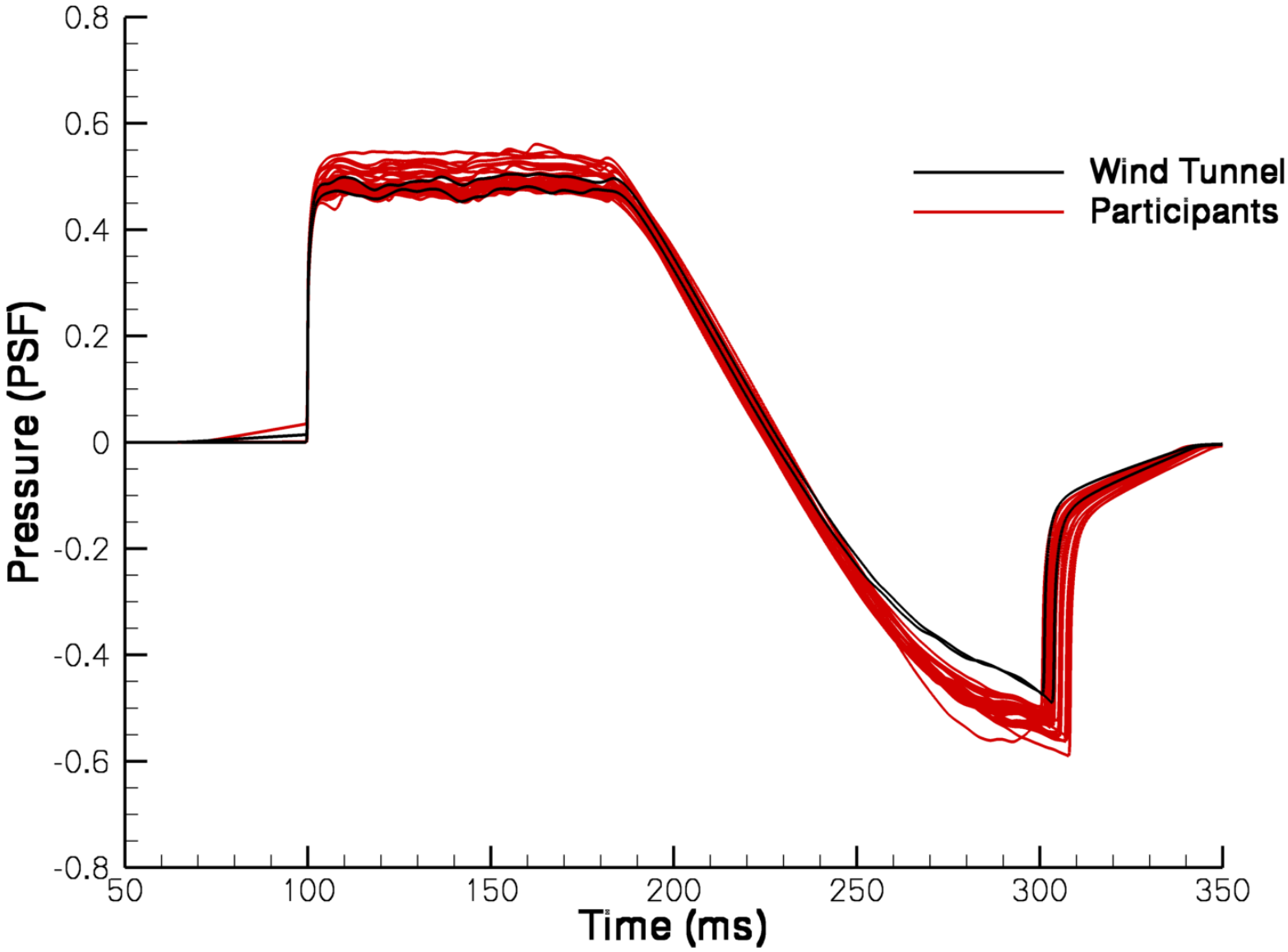


Ground Propagation

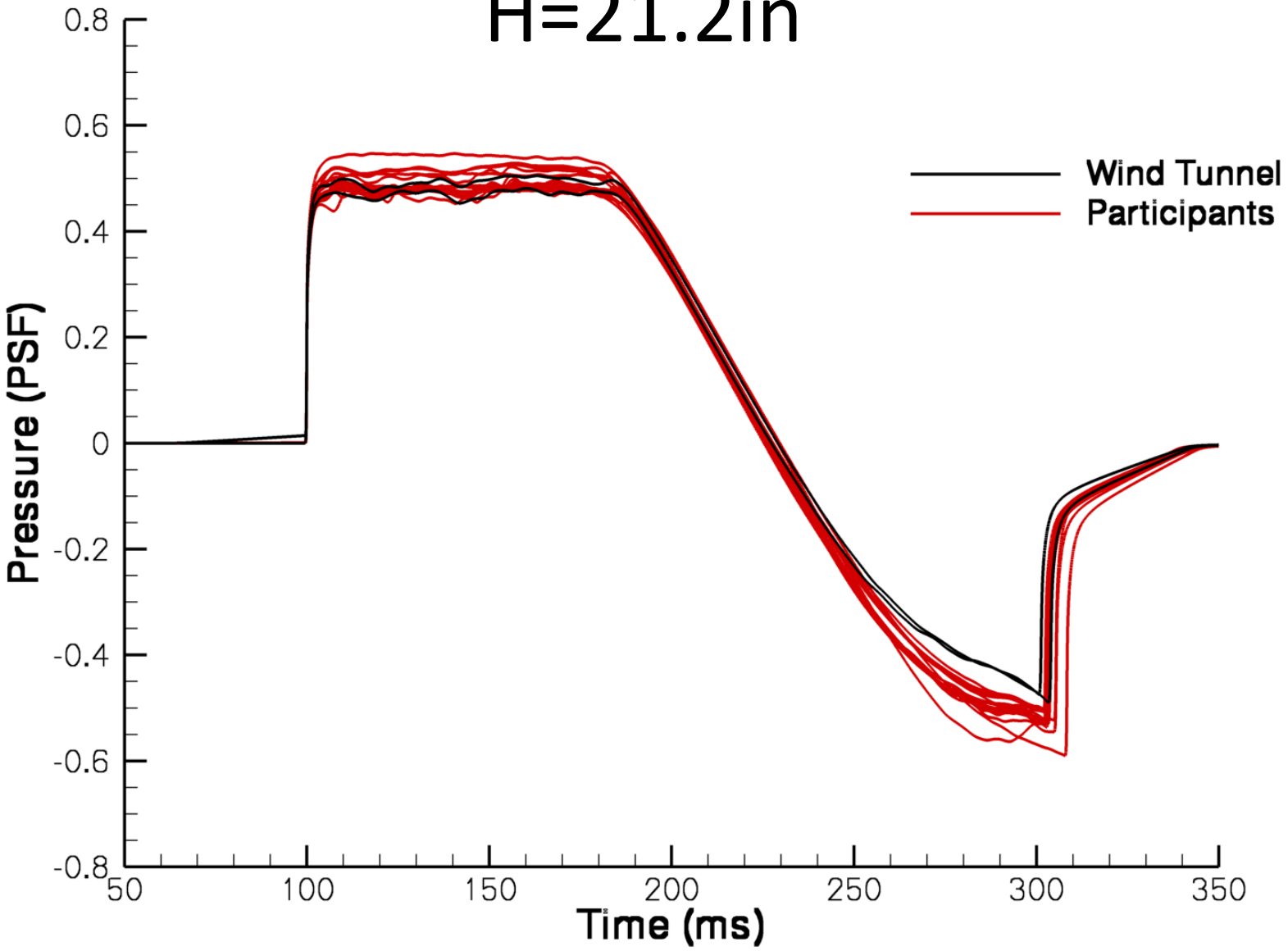
- Assume flight conditions of “full-scale”
  - Scale x-dimension of the signature
    - 0.006 scale SEEB-ALR
    - 0.0065 scale Delta Wing Body
    - 0.008 scale LM1021
  - 55 thousand foot altitude
  - Standard atmosphere
- sBOOM (Rallabhandi)
  - Burgers equation with molecular relaxation



All SEEB-ALR Ground from H=21.2in



Finest-Grid SEEB-ALR Ground from H=21.2in



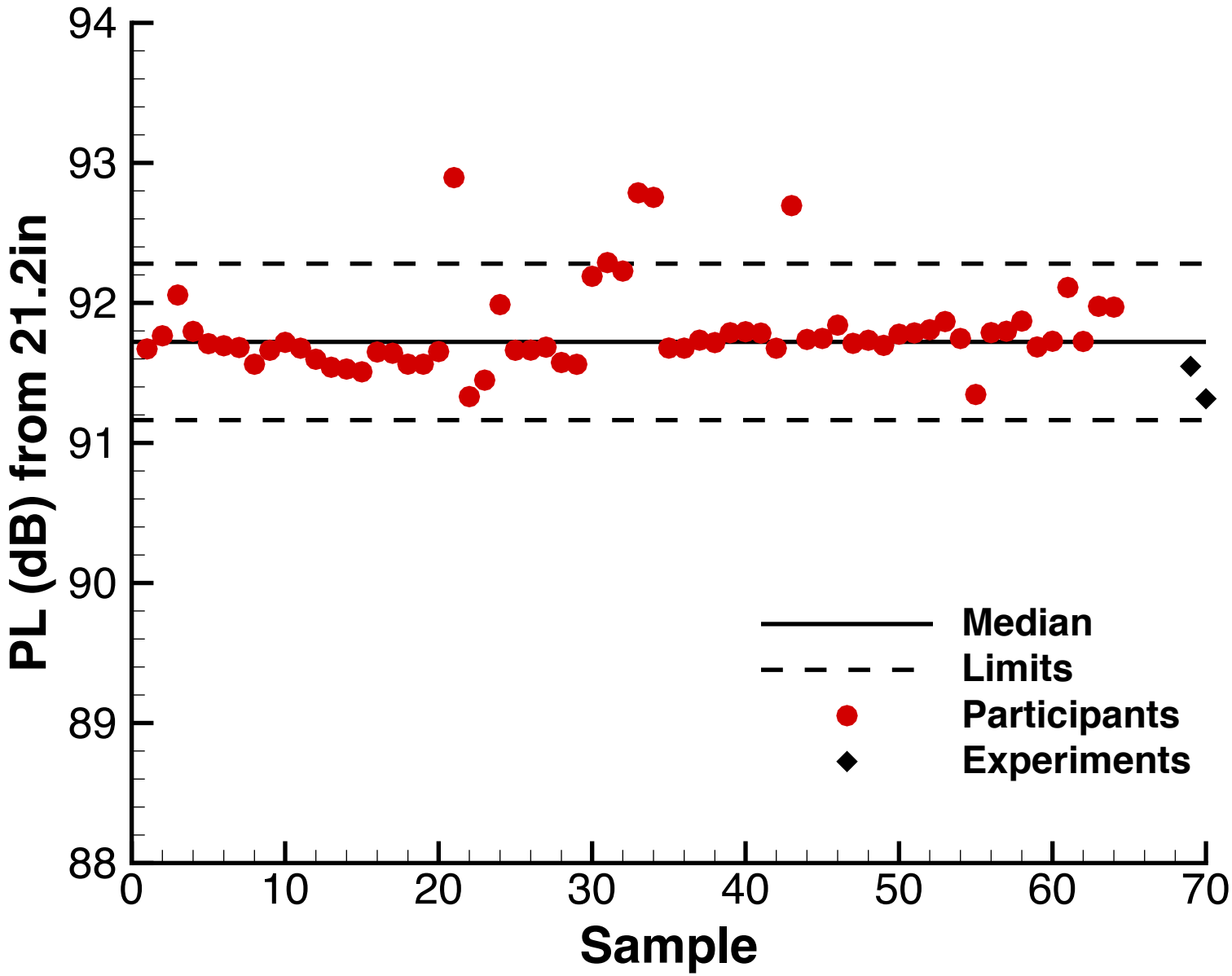
Loudness Measures

- Inherently a subjective metrics
- The human experiences of loudness and annoyance are correlated to noise descriptors through experiments (Leatherwood et al. JASA 2002)
  - Stevens Mark VII Perceived Level (PL)
- Average person can discern differences on the order of 2 PL (dB)

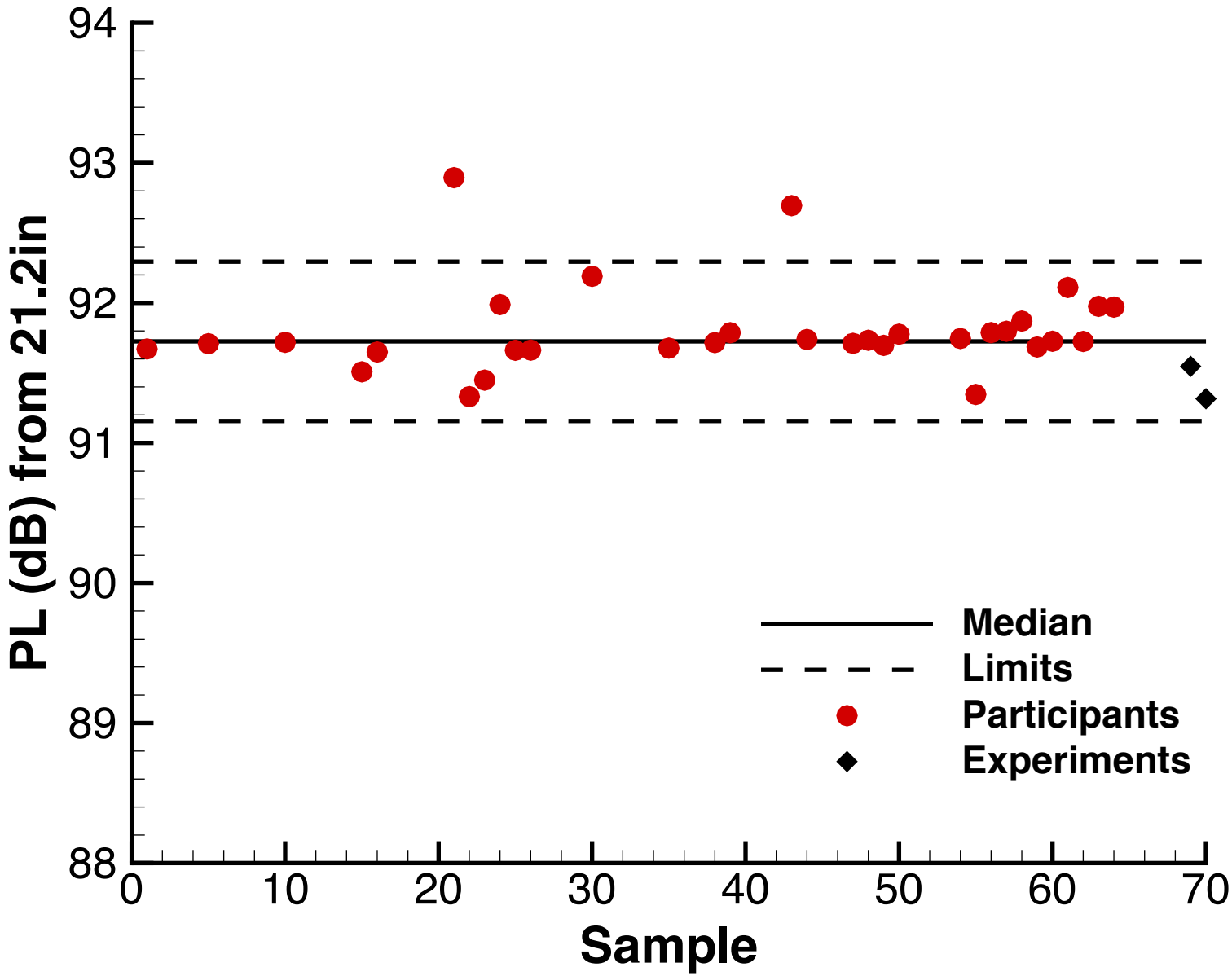
Statistical Method

- Goal is to identify “different” results, not “correct” or “wrong”
- Median +/- (coverage factor)*(std. dev.)
  - Assume a uniform distribution
- Small sample size with correlated results (same person, same code, refined grids)
- Used by other workshops

All SEEB-ALR Perceived Level

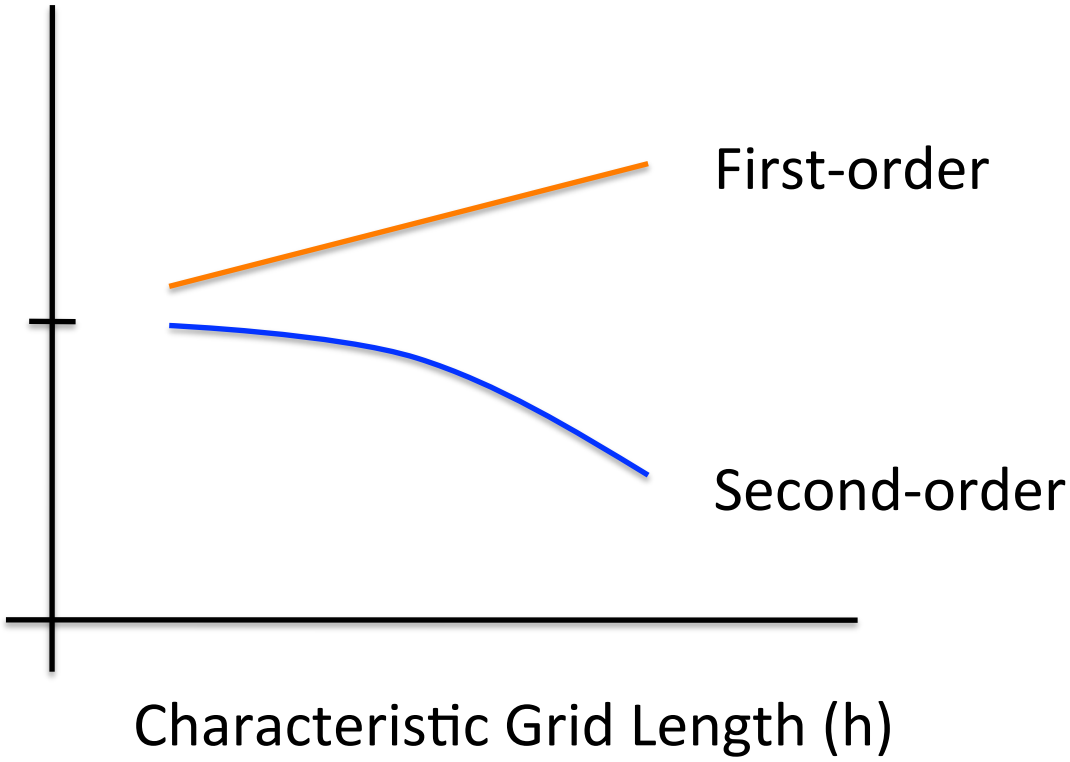


Finest-Grid SEEB-ALR Perceived Level

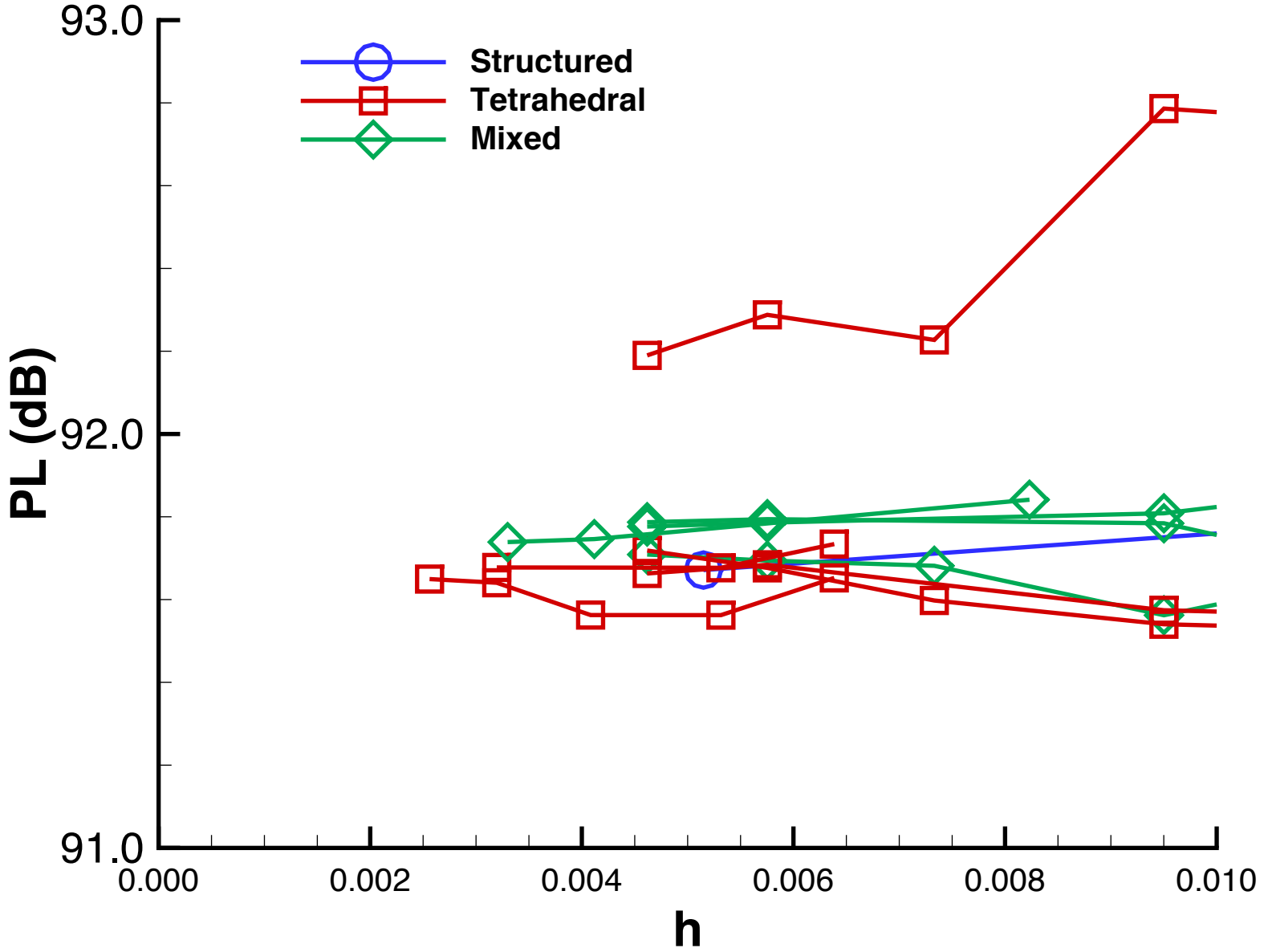


Expected Grid Convergence

- Consistent methods should approach a value as the grid is refined to “zero” h

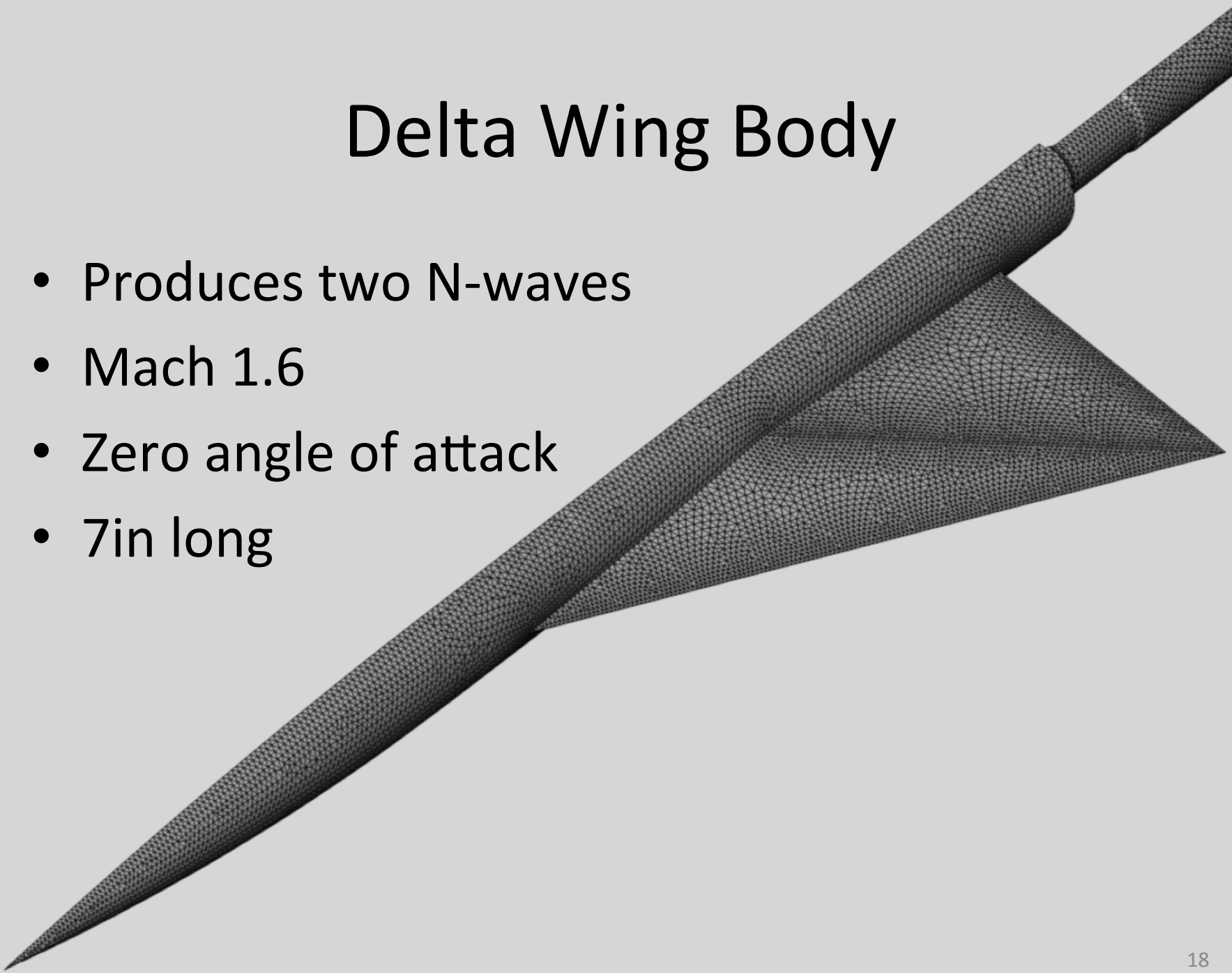


SEEB-ALR Perceived Level



Delta Wing Body

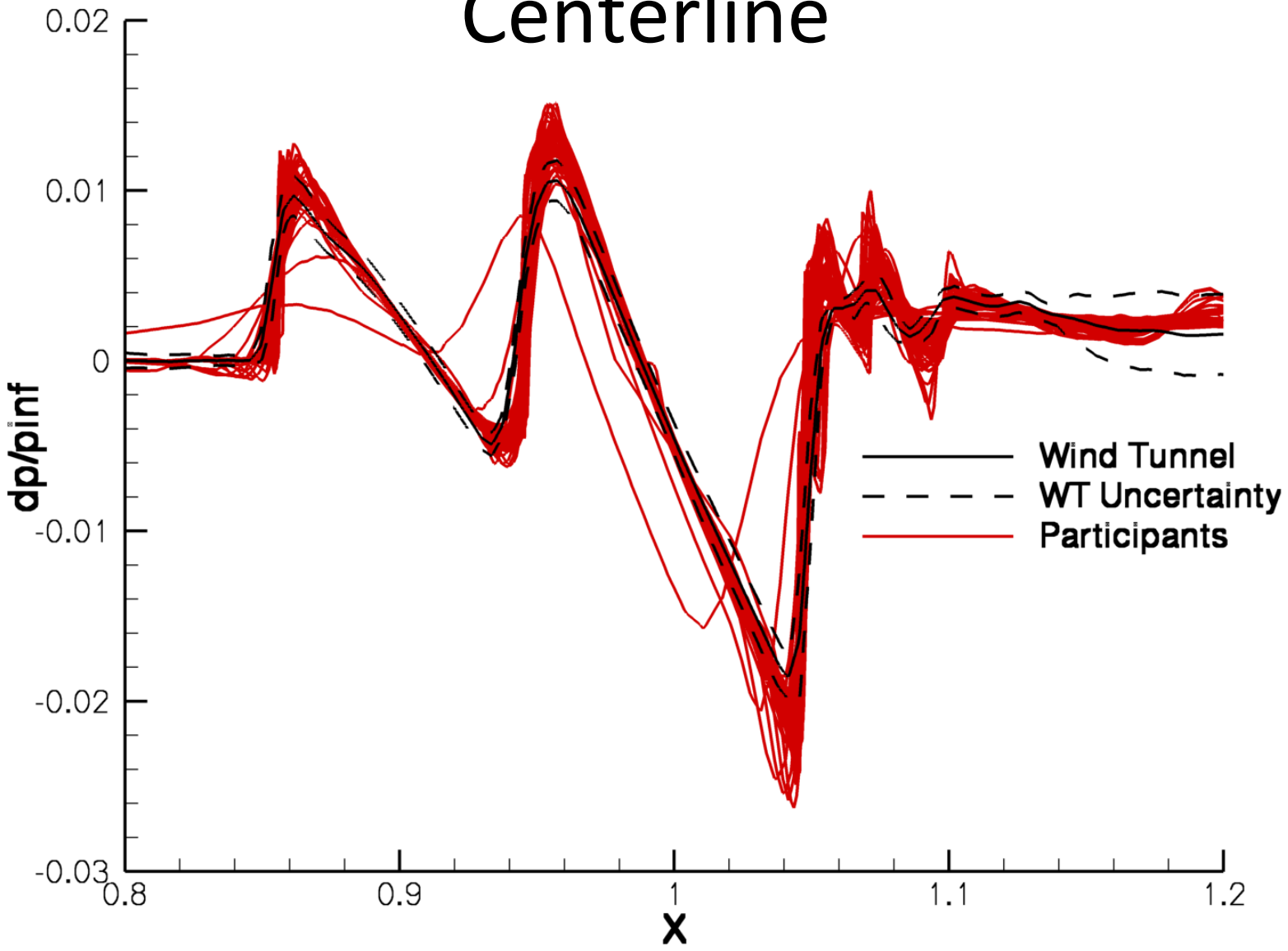
- Produces two N-waves
- Mach 1.6
- Zero angle of attack
- 7in long



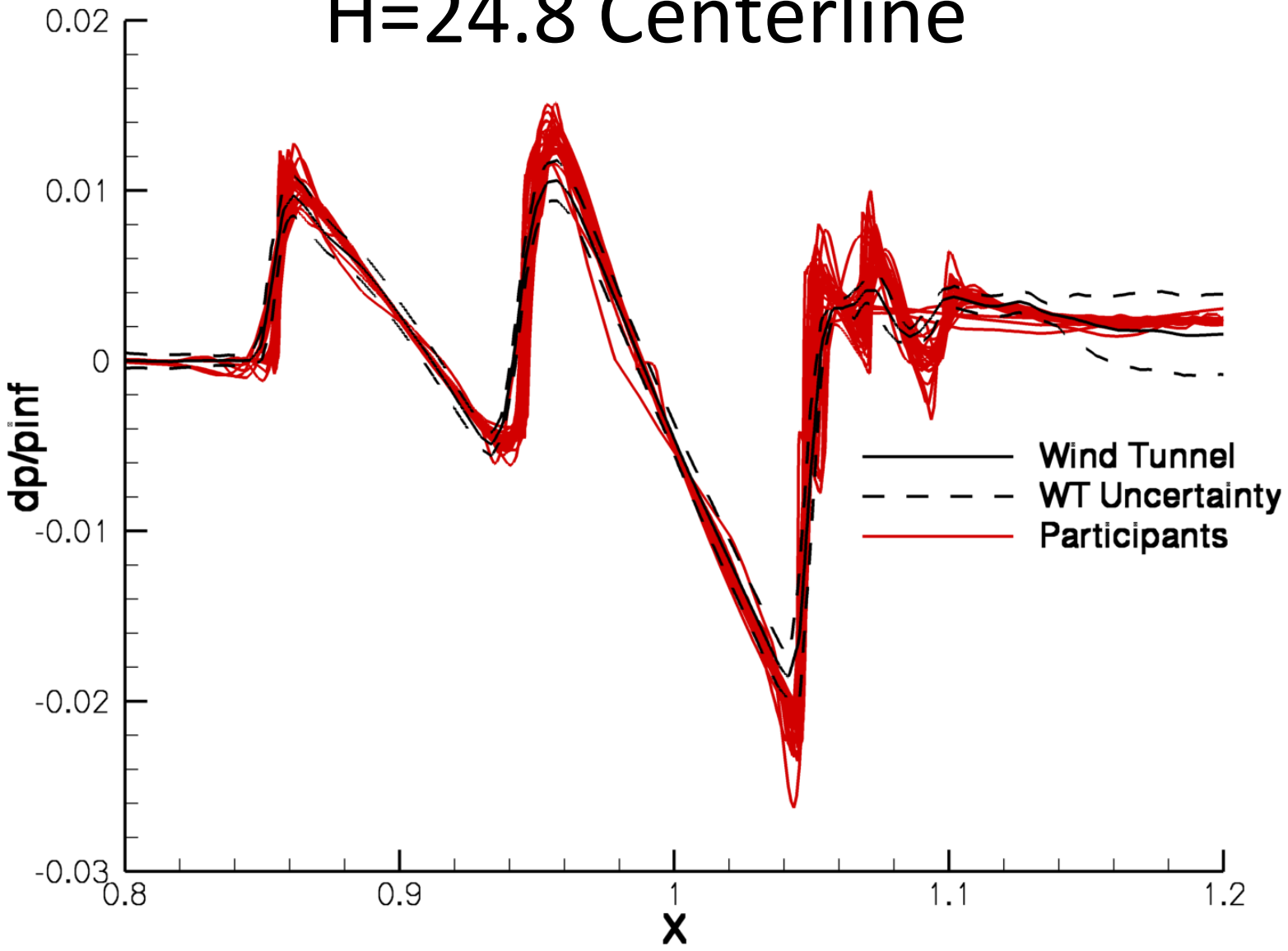
Delta Wing Body Signatures

- 60 sets of extracted signatures (10 locations)
  - 42 workshop grids
    - Uniformly refined unstructured mixed-element and purely-tetrahedral
    - Point-matched structured (every other node)
  - 18 participant generated
    - Fixed and solution adapted
  - 25 tetrahedral, 19 mixed, 8 structured, 4 Cartesian, 3 overset, 1 hybrid
  - 56 Euler, 4 SA
  - 9 new or updated since the workship

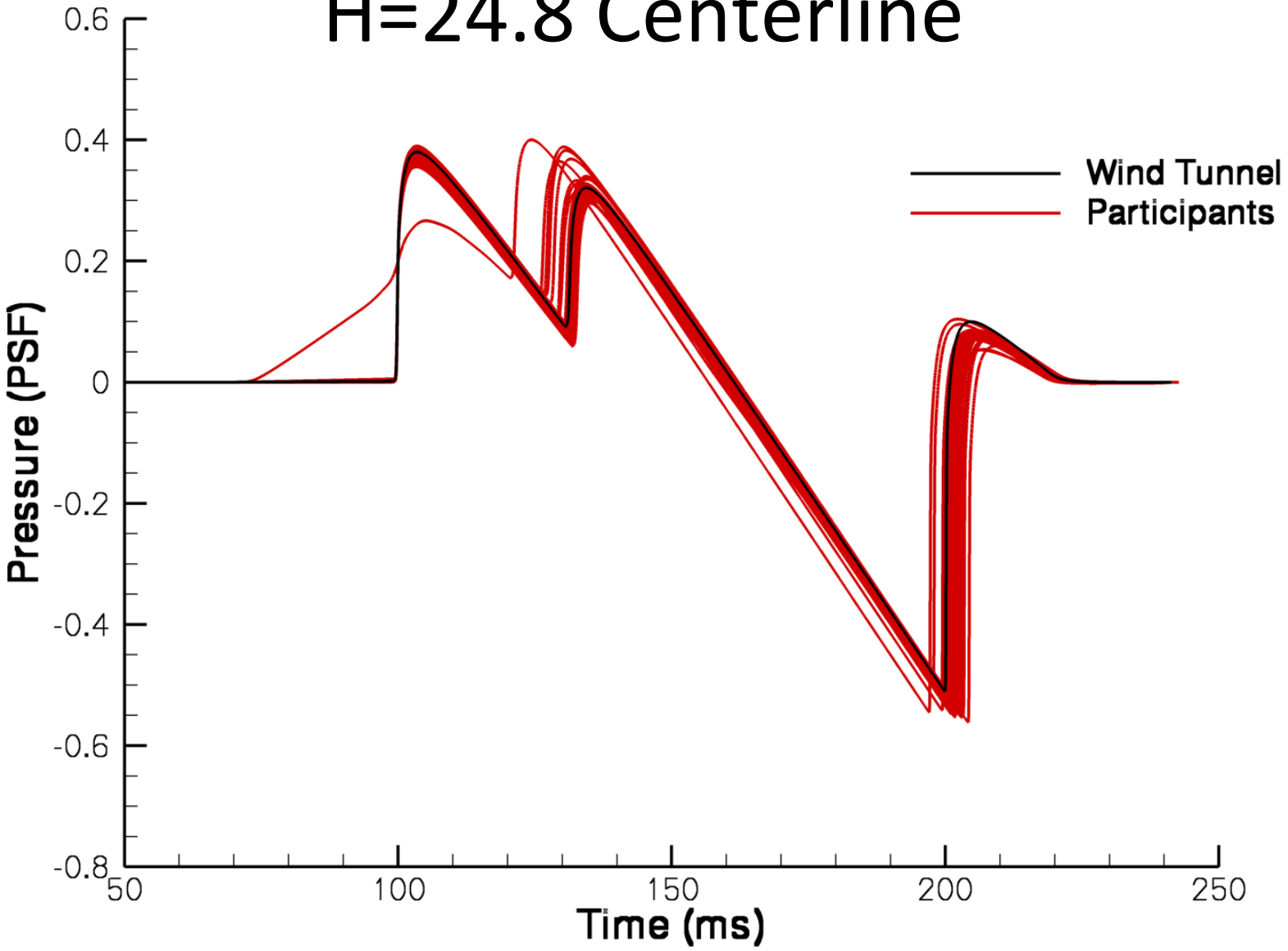
All Delta Wing Body Signatures H=24.8 Centerline



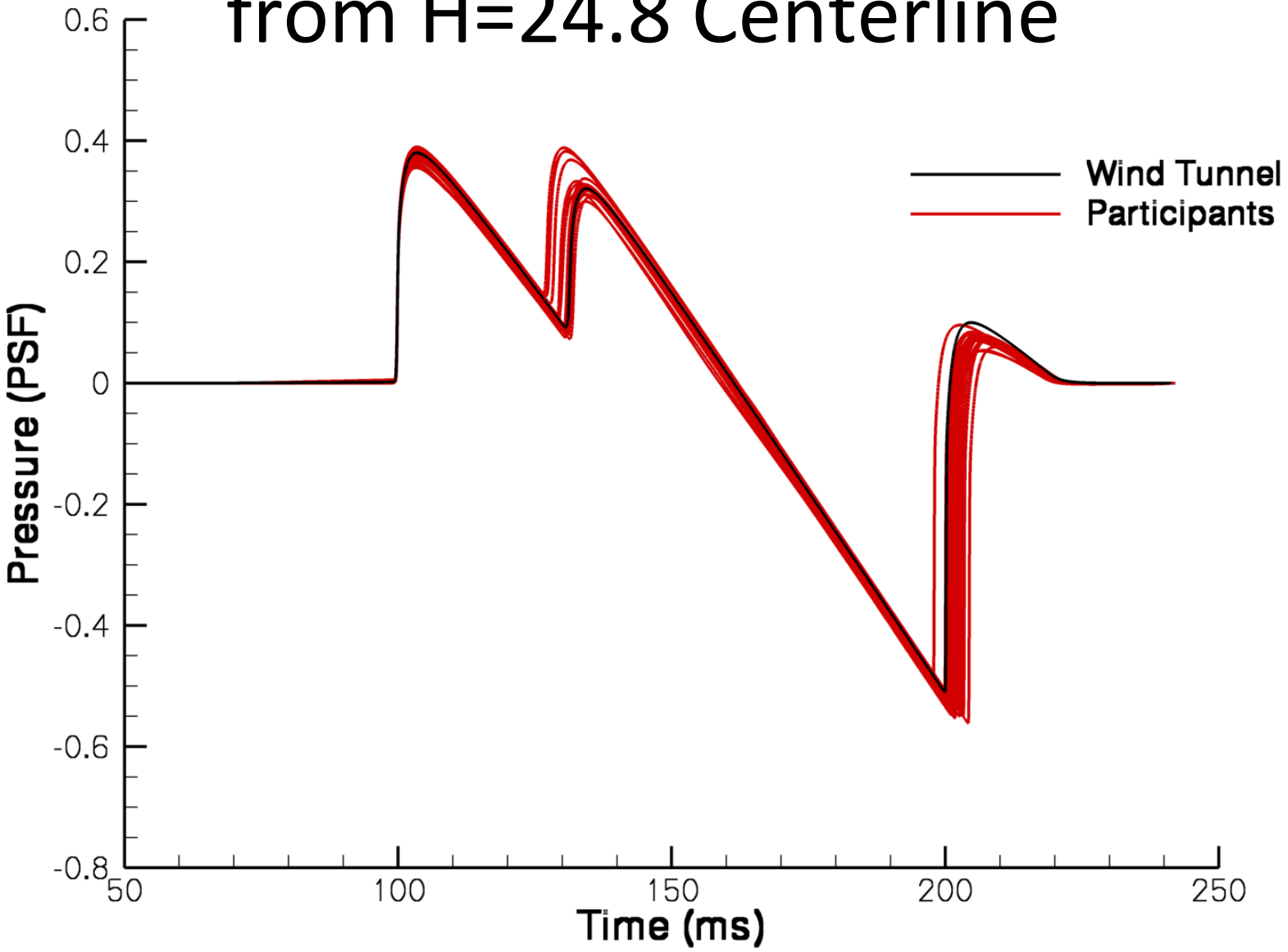
Fine-Grid Delta Wing Body Signatures H=24.8 Centerline



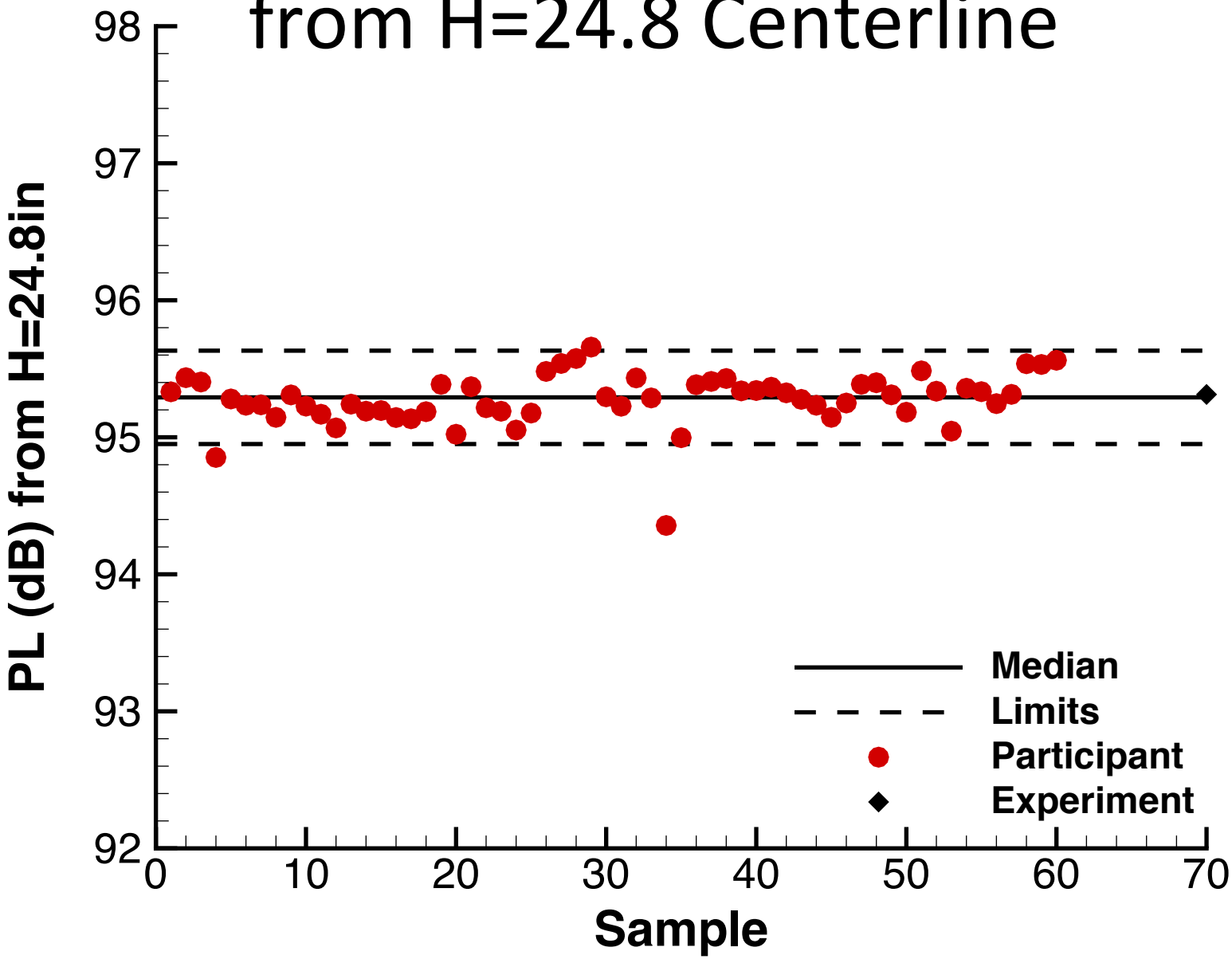
All Delta Wing Body Ground from H=24.8 Centerline



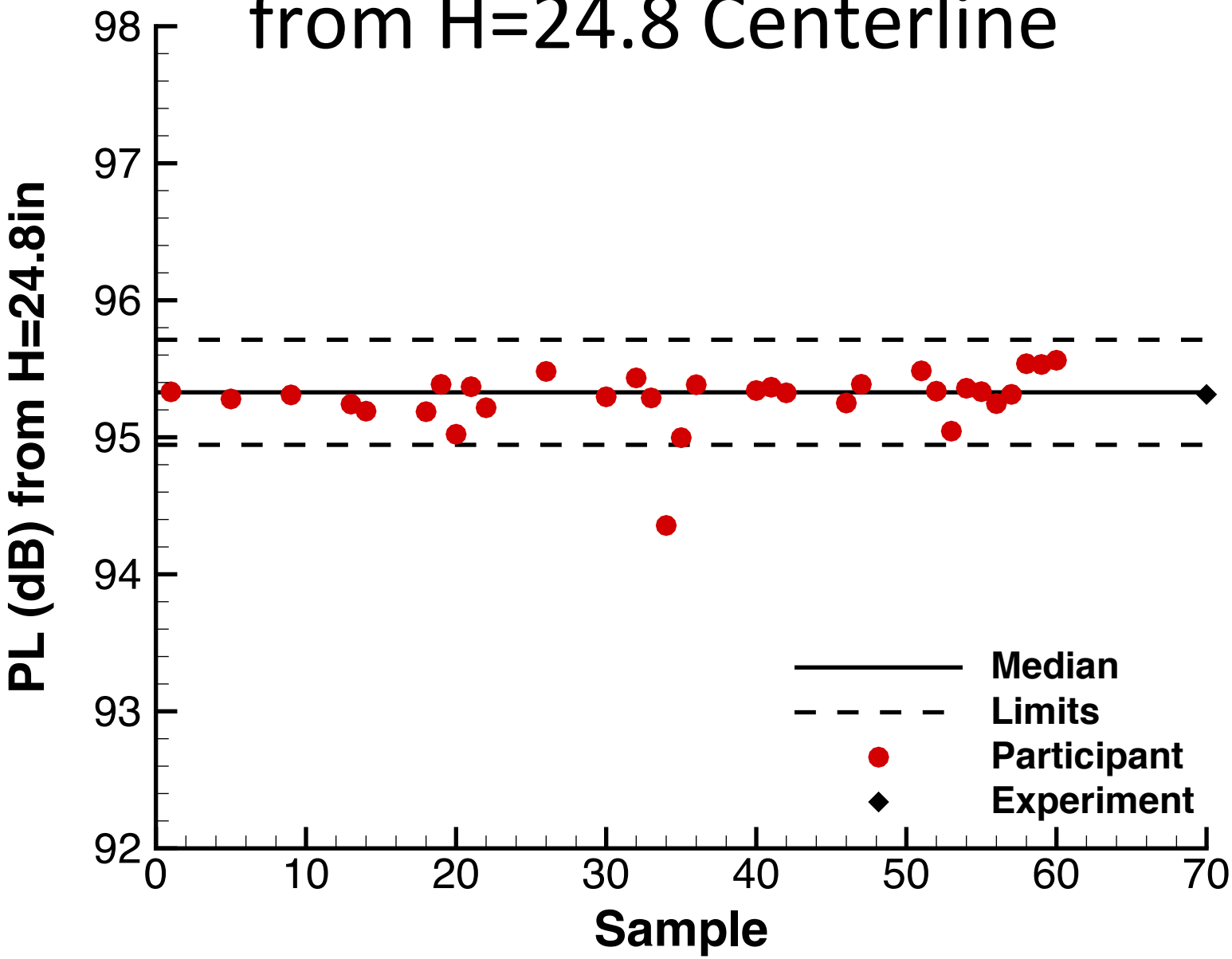
Fine-Grid Delta Wing Body Ground from H=24.8 Centerline



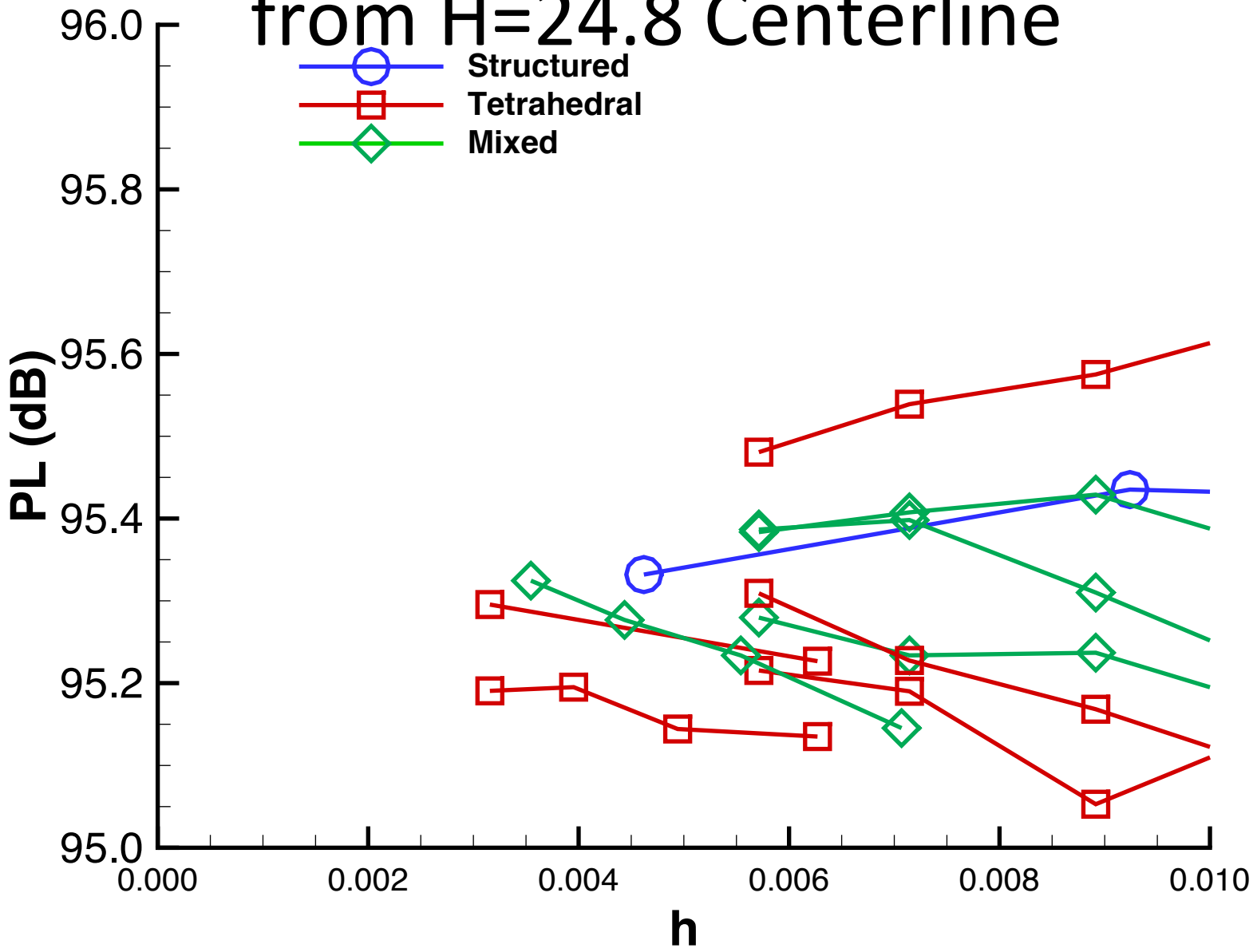
All Delta Wing Body Perceived Level from H=24.8 Centerline



Fine-Grid Delta Wing Body Perceived Level from H=24.8 Centerline

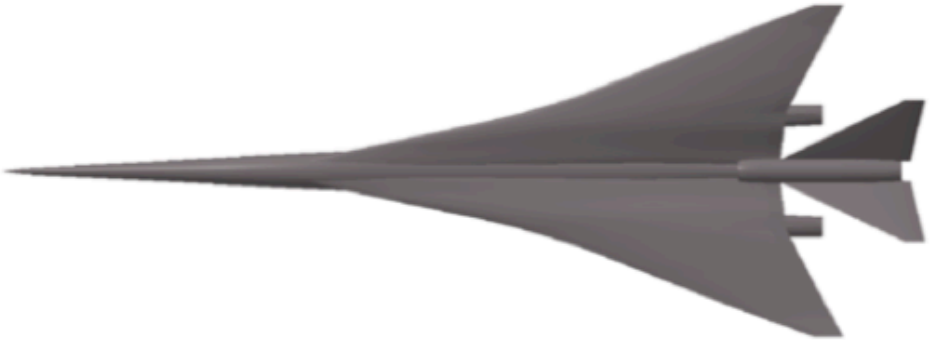


Delta Wing Body Perceived Level from H=24.8 Centerline



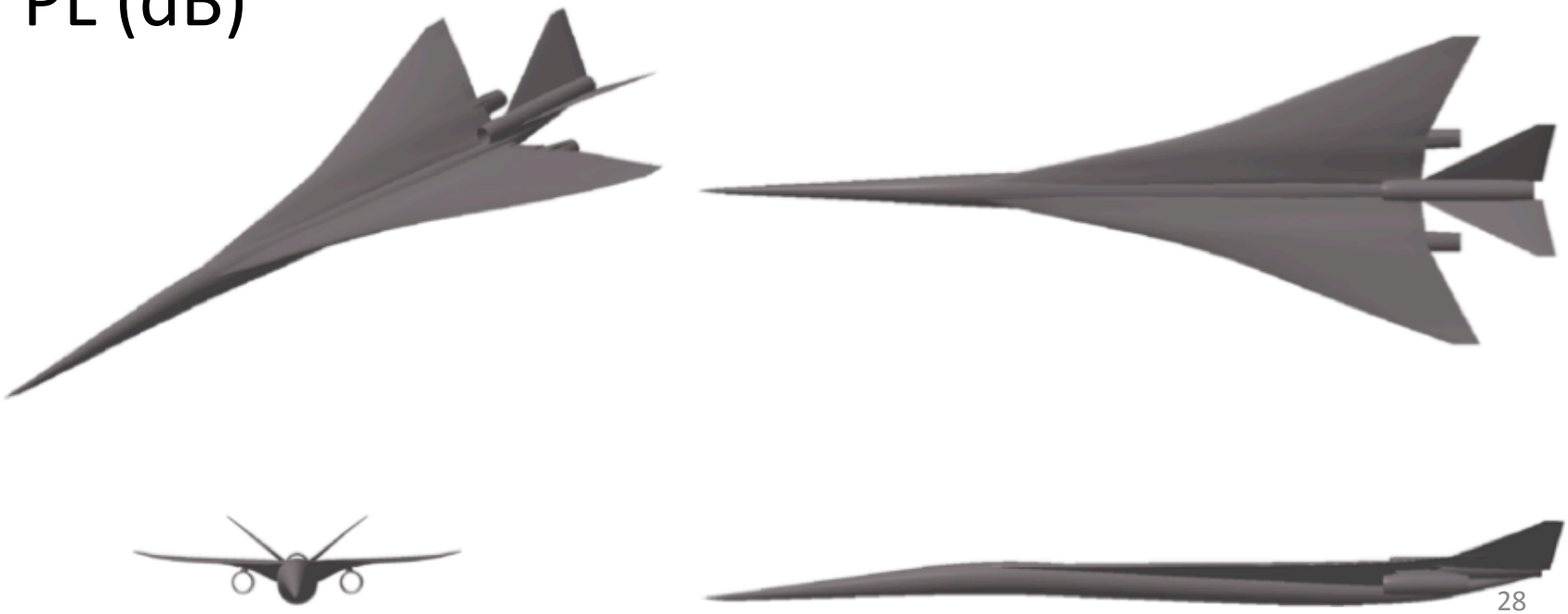
LM1021

- Complex configuration with wing, body, tails, and nacelles at 2.1 degree angle of attack
- 22.4in long, 4in half span
- Mach 1.6



LM1021

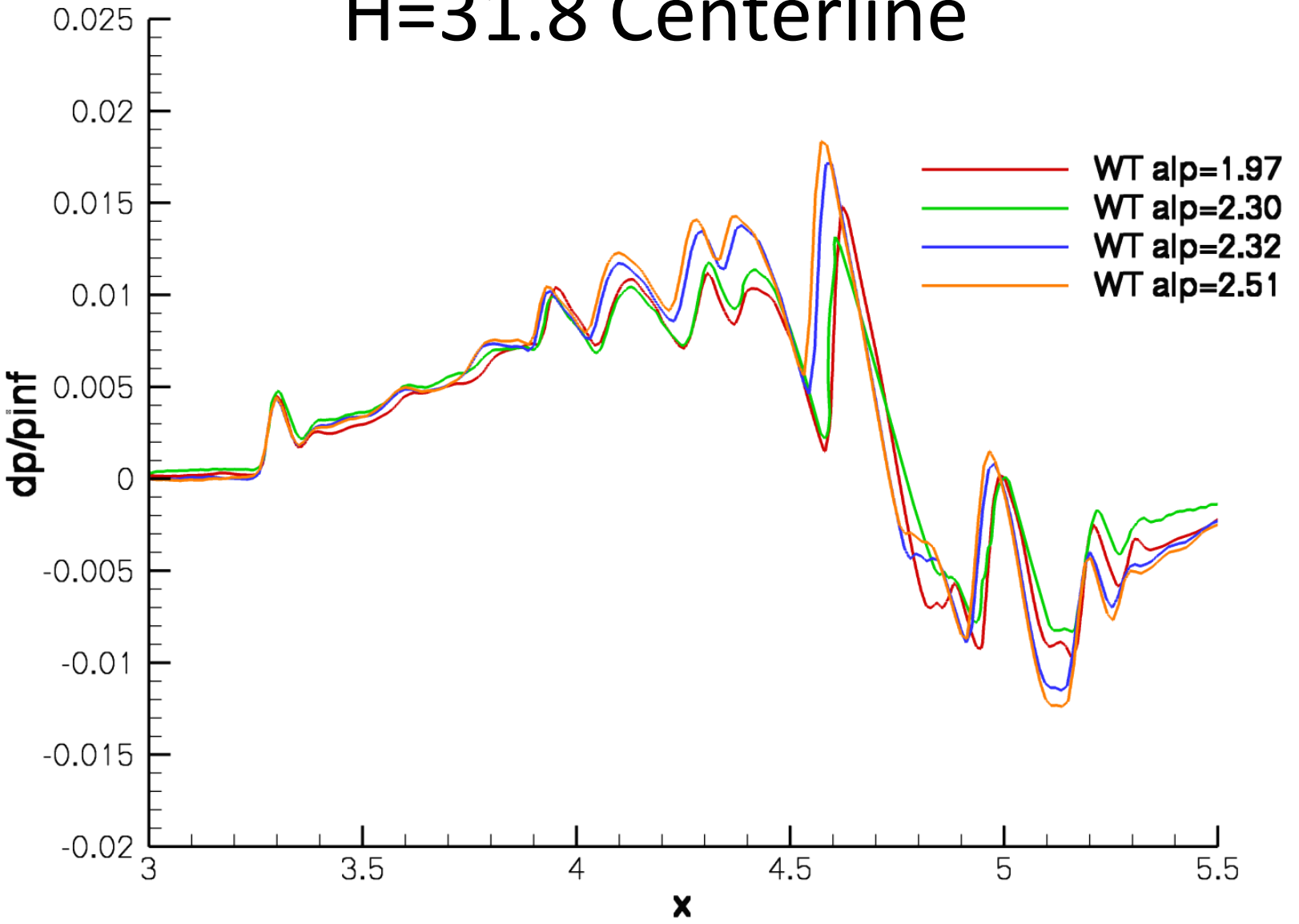
- Wind tunnel Reynolds number and blade sting mount increase loudness
- Full-scale free-flight has a typical carpet of 85 PL (dB)



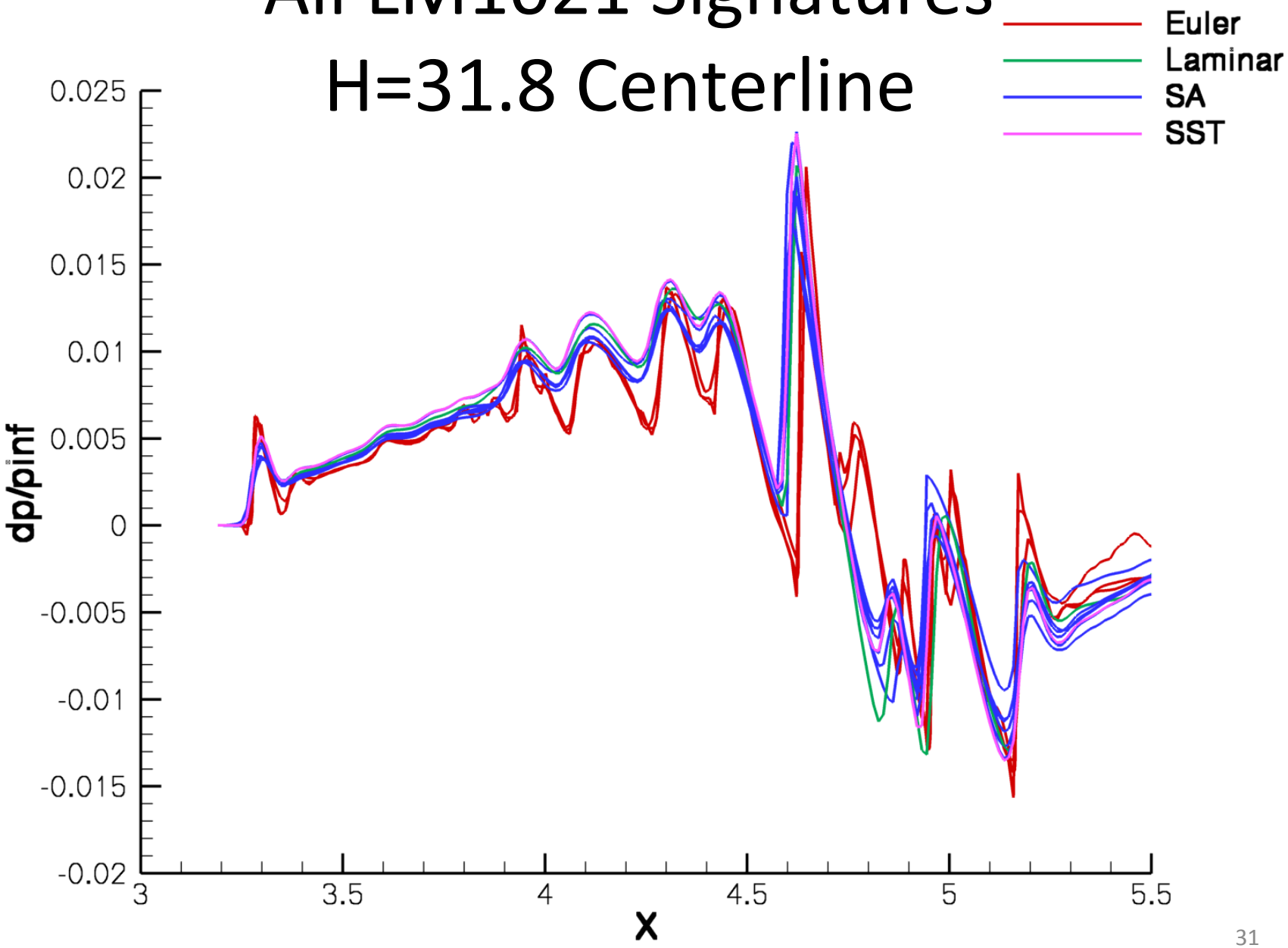
LM1021 Signatures

- 11 sets of extracted signatures (5 cylinders)
  - 5 workshop grids
    - Single purely-tetrahedral grid with turbulent spacing
  - 6 participant generated
    - Fixed and solution adapted
  - 9 tetrahedral, 1 Cartesian, 1 hybrid
  - 6 SA, 3 Euler, 1 SST, 1 laminar
  - 2 new or updated since the workshop

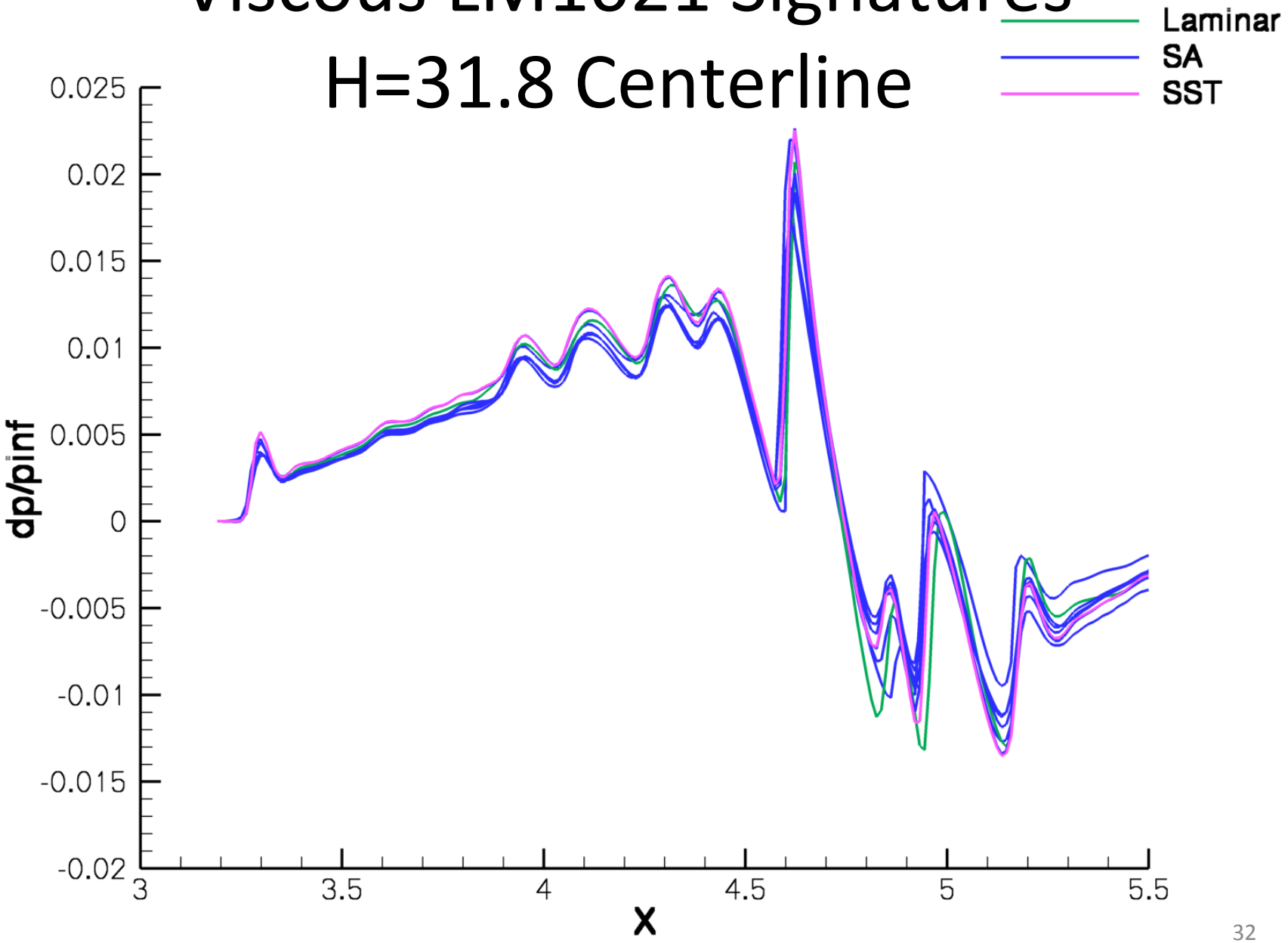
Wind Tunnel LM1021 Mean Signatures H=31.8 Centerline



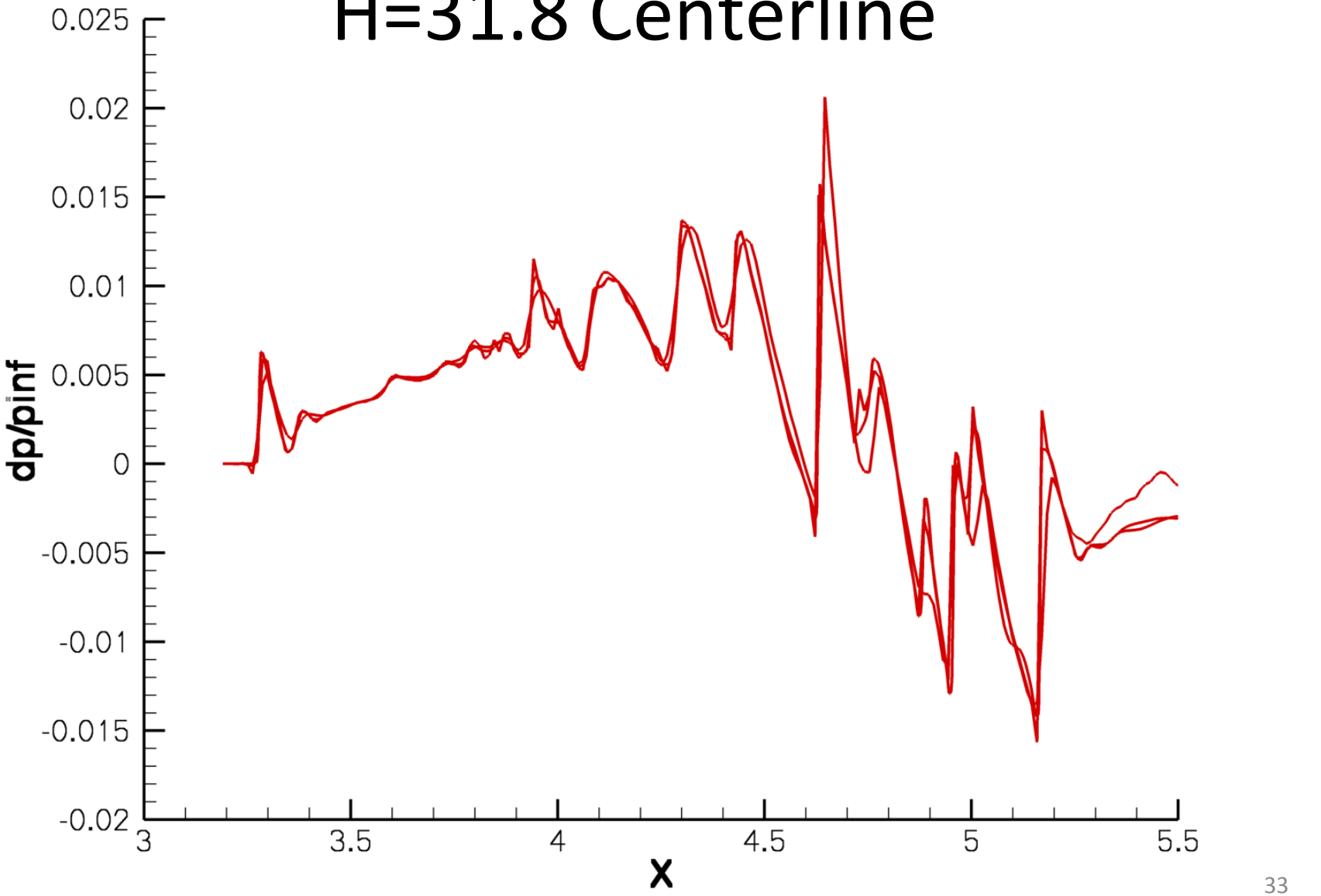
All LM1021 Signatures
H=31.8 Centerline



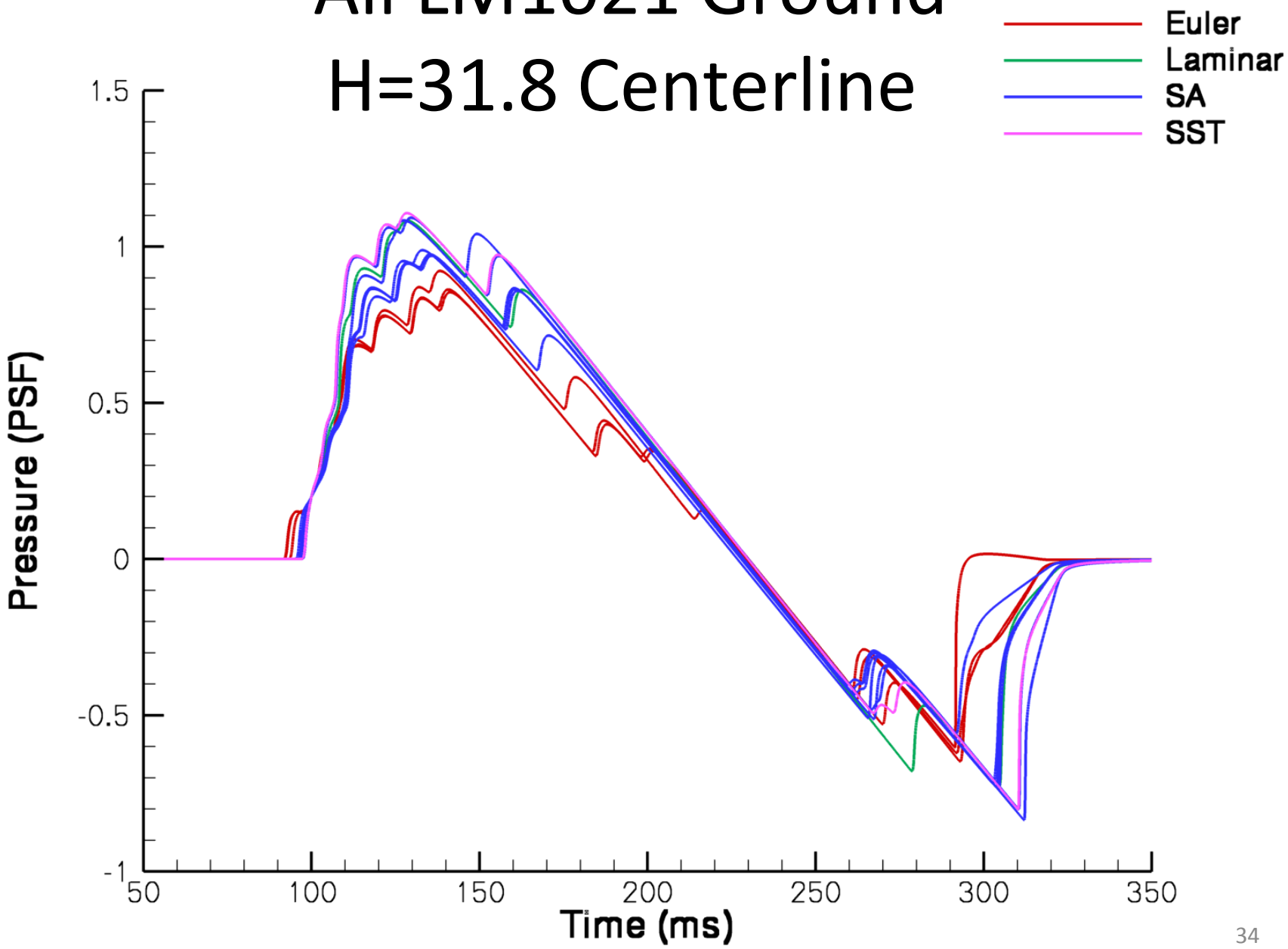
Viscous LM1021 Signatures
H=31.8 Centerline



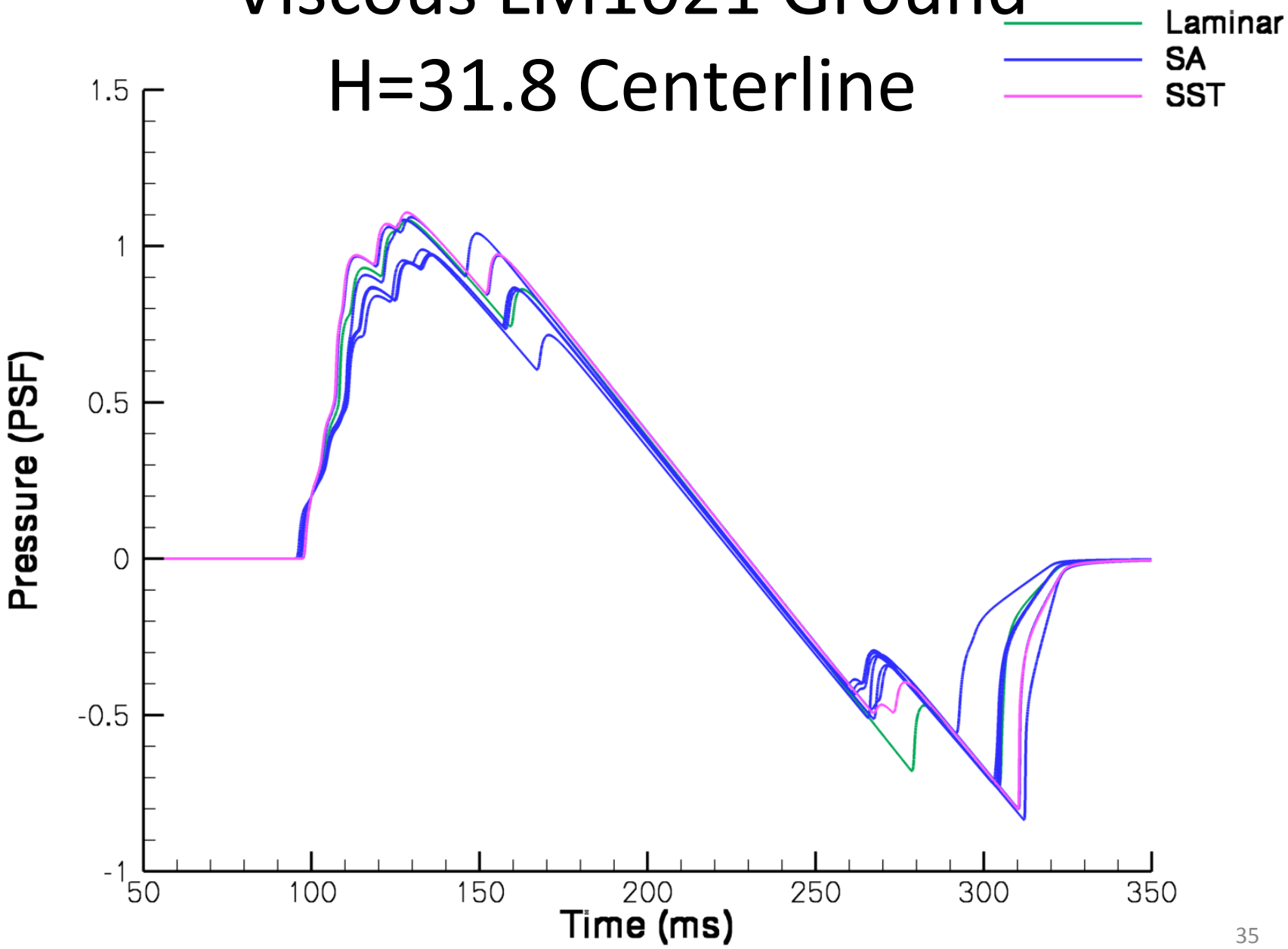
Euler LM1021 Signatures H=31.8 Centerline



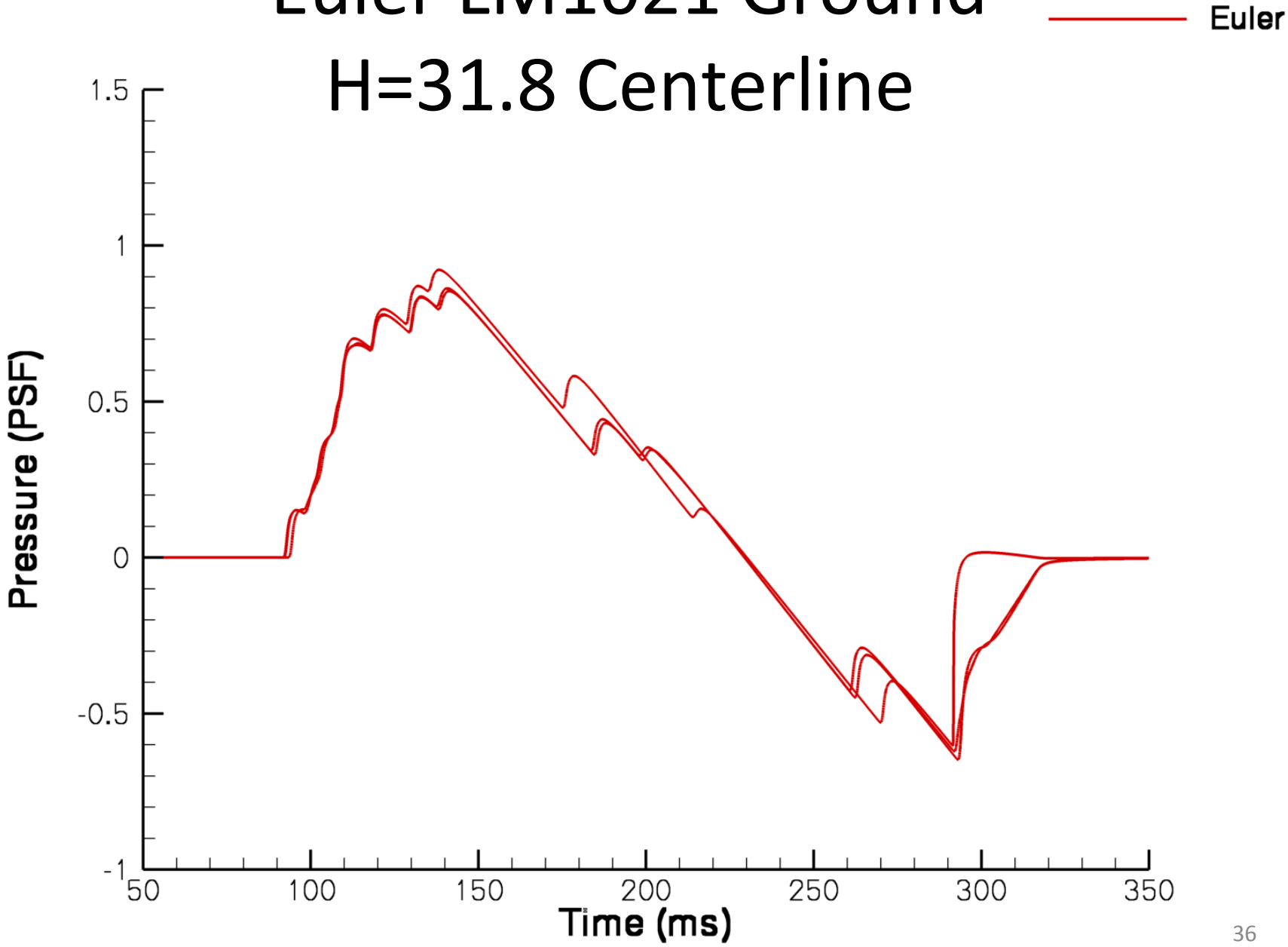
All LM1021 Ground H=31.8 Centerline



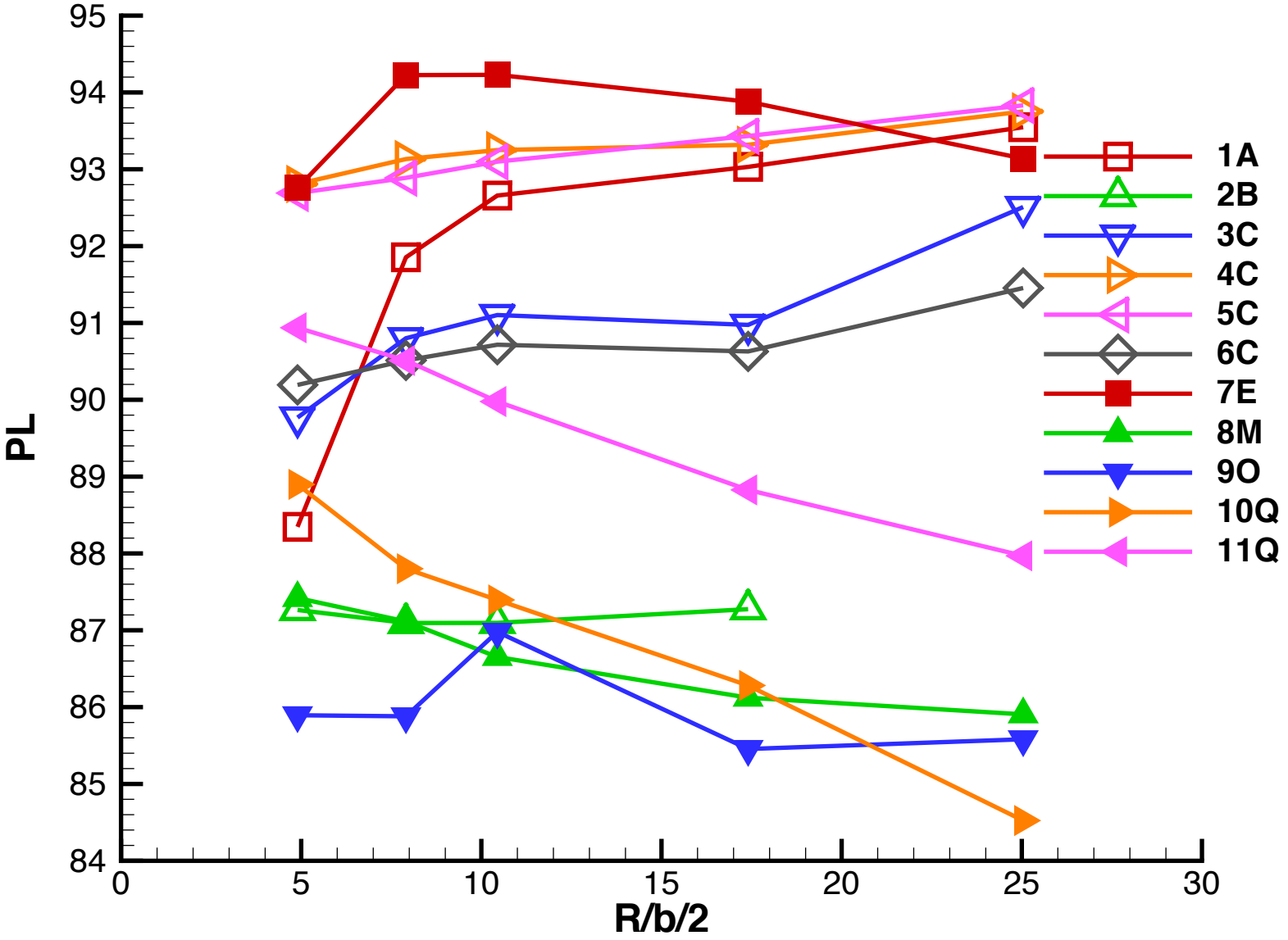
Viscous LM1021 Ground H=31.8 Centerline



Euler LM1021 Ground H=31.8 Centerline



LM1021 Centerline Perceived Level



In the Paper

- LM1021 near-field correction (influence of spanwise distribution of acoustic disturbances), equivalent area, boom carpets, and spectra
- SEEB-ALR and DWB validation metric (norm of the difference between simulation and measurement)
- DWB off-track statistics
- Detailed examination of outliers
- Recommendations and future steps

Conclusions

- Successful first workshop with international participation that includes government agencies, industry, and academia
- The simpler required configuration each had 60+ submissions
- The optional full-configuration case had 11 submissions

Conclusions

- SEEB-ALR: 91.8 PL (dB) median, 0.3 dB standard deviation
- Delta Wing Body on centerline: 95.5 PL (dB) median, 0.2 dB standard deviation
- Resubmission of data lowered the workshop standard deviations (0.5 and 0.3)
- LM1021 wind tunnel configuration: large 85 PL (dB) to 95 PL (dB) variation and small sample size (no statistics)

Conclusions

- Exclusion of coarser grids in the uniform grid refinement study had a negligible effect on median and limits for SEEB-ALR and Delta Wing Body
- A uniform grid refinement study may have provided insight into the LM1021 PL sensitivity
- LM1021 signature was more sensitive to inviscid and viscous simulations than simpler configurations

Participate

- Visit http://lbpw.larc.nasa.gov for
  - Presentations and references
  - Geometry, grids, submitted data, and derived data are available: **independent analysis encouraged!**
  - Sign up for the low-traffic announcement e-mail list
- See you for the next workshop (tentatively 2017)